IGRP Background

- IGRP stands for Interior Gateway Routing Protocol
  - designed and deployed successfully in 1986 by Cisco Systems
  - proprietary protocol

Reason for IGRP?
- At this time there was no alternative for RIP available
- RIP disadvantages:
  - Metric limitation
    - max. 15 hops (16 hops = network unreachable)
    - Hop count doesn't reflect the capacity of the transmission media
    - takes the least hop path instead of the fastest or "best path"
    - didn't allow flexible routing in complex environments
  - much routing overhead (full routing table every 30 seconds)

IGRP at a glance

- Distance vector protocol (can only be used within an Autonomous System)
- Composite metric
  - Bandwidth
  - Delay
  - Reliability
  - Loading
- Implementation of loop avoidance mechanisms
- Support of multiple unequal-metric paths
- Faster convergence than RIP
IGRP / EIGRP Metric calculation

- **Bandwidth**
  - unit: bits/sec
  - default values for LANs:
    - corresponding to real bandwidth
  - default values for serial lines:
    - corresponding to bandwidth of 1.544Mbps (T1 line)
    - configuration of the real bandwidth on serial lines is a must!!!
  - cisco interface command: `bandwidth <number in kbit/s>`
  - minimum bandwidth along a path is taken
  - $BW_{IGRP}$ is expressed by $(1/bandwidth) \times 10^{17}$
  - $BW_{EIGRP}$ is expressed by $(1/bandwidth) \times 10^{17} \times 256$
  - The range is from a 1200bps line to 10 terabits per second

- **Delay**
  - unit: 10 microseconds
  - it is the sum of the transmission delays along the path and is stored in a 32-bit field, in increments of 39.1 nanoseconds
  - all 1's indicates an unreachable destination
  - default values for LANs:
  - corresponding to real delay
  - default values for serial lines:
    - corresponding to delay of 1.544Mbps (T1 line)
    - configuration of the real delay on serial lines is an option
    - cisco interface command: `delay <number in tens of usec>`
  - $Delay_{IGRP}$ is expressed by $(delay/10)$
  - $Delay_{EIGRP}$ is expressed by $(delay/10) \times 256$

### Bandwidth

<table>
<thead>
<tr>
<th>Bandwidth</th>
<th>BW_{IGRP}</th>
<th>BW_{EIGRP}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite</td>
<td>5.120</td>
<td>20</td>
</tr>
<tr>
<td>Ethernet (500 Mbit/s)</td>
<td>256.000</td>
<td>100</td>
</tr>
<tr>
<td>Ethernet (100 Mbit/s)</td>
<td>256.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Ethernet (10 Mbit/s)</td>
<td>640.000</td>
<td>2.500</td>
</tr>
<tr>
<td>Token Ring (4 Mbit/s)</td>
<td>160.000</td>
<td>625</td>
</tr>
<tr>
<td>Token Ring (16 Mbit/s)</td>
<td>256.000</td>
<td>100</td>
</tr>
<tr>
<td>Satellite (500 Mbit/s)</td>
<td>1.657.856</td>
<td>6.476</td>
</tr>
<tr>
<td>128 kbps</td>
<td>20.000.000</td>
<td>78.125</td>
</tr>
<tr>
<td>64 kbps</td>
<td>40.000.000</td>
<td>106.250</td>
</tr>
<tr>
<td>56 kbps</td>
<td>45.714.176</td>
<td>178.571</td>
</tr>
<tr>
<td>10 kbps</td>
<td>256.000.000</td>
<td>1.000.000</td>
</tr>
<tr>
<td>1 kbps</td>
<td>2.560.000.000</td>
<td>10.000.000</td>
</tr>
</tbody>
</table>
IGRP Metric calculation

- Reliability
  - arbitrary number
  - 255 means 100%
  - 1 means 0%
  - worst reliability between source and destination
  - dynamically measured
    - keepalives are sent off the interface every 10 seconds, frame has CRC
    - samples are calculated over 5 minutes
  - time interval needs reconfiguration, when Reliability is used

- Loading
  - arbitrary number
  - load is given as a fraction of 255. A load of 255 indicates a completely saturated link
  - dynamically measured
    - calculated over 5 minutes
    - time interval needs reconfiguration, when Loading is used

Formula for metric calculation
- defaults:
  - \( k_1 = 1, \ k_2 = 0, \ k_3 = 1, \ k_4 = 0, \ k_5 = 0 \)
  - \( K_1 \text{ to } K_5 \) are arbitrary numbers which can be configured

\[
\text{metric} = \left( k_1 \cdot \text{min BW}_{\text{tar}} + \frac{k_2 \cdot \text{min BW}_{\text{tar}}}{256 - \text{load}} + k_3 \cdot \text{sumDelay}_{\text{tar}} \right) + \frac{k_4 \cdot \text{reliability}}{k_5}
\]

If \( k_5 \) doesn’t equal 0, an additional operation is done

\[
\text{compositeMetric} = k_1 \cdot \text{min BW}_{\text{tar}} + k_3 \cdot \text{sumDelay}_{\text{tar}}
\]

For default values of \( k \) parameters:

\[
\text{compositeMetric} = k_1 \cdot \text{min BW}_{\text{tar}} + k_3 \cdot \text{sumDelay}_{\text{tar}}
\]
IGRP Metric example 2

\[ \text{Metric} = \text{BW} + \text{delay} = 78125 + 2000 = 80125 \]

\[ \text{Metric} = \text{min. BW along the path} + \text{sum of delays} = 6476 + 2000 + 2000 = 10476 \]

IGRP multiple paths

- Support of up to 6 parallel paths (default: 4) to the destination for load balancing
  - default: same metric for parallel paths is necessary
- Support of unequal-metric load balancing
  - Prerequisite: configuration of a variance factor
  - The alternative path metric must be within the specified variance of the best local metric

IGRP Metric

- Routing updates also include a count of hops and a computation of the path MTU
  - \( \Rightarrow \) max. network diameter 255 hops (IP TTL-field)
  - default: 100 hops
IGRP & default routes

- RIP and OSPF are using 0.0.0.0 as their default route (=>metric is not related to a distance)
- IGRP allows to mark real networks as „candidates for being default“
  - e.g., if multiple exit points to the Internet exist, then this implementation allows to choose the optimal „border router“

IGRP Loop avoidance & timers

- Periodical Routing updates
  - destination address: 255.255.255.255
- Topology changes are reported with triggered updates
- Hold-downs
- Split horizon
- Route Poisoning Updates
  - are intended to defeat larger routing loops
  - are sent if a route metric has increased by a factor of 1.1 or greater

IGRP Protocol stack

OSI stack

- IP protocol number 9 (decimal)
- Physical layer
- Data link layer
- IGRP
Agenda

- IGRP
- EIGRP

EIGRP Background

- **EIGRP** stands for **Enhanced Interior Gateway Routing Protocol**
  - proprietary protocol
  - tries to combine the advantages of the distance vector and the link state protocol world without their specific problems
  - Distance vector
    - advantages:
      - less CPU power and memory usage, simple configuration
    - disadvantages:
      - slow convergence, lot of routing overhead, possibility of loops
  - Link state
    - advantages:
      - fast convergence, no loops, better metric (cost factor)
    - disadvantages:
      - high CPU power and memory usage (SPF algorithm, LS database), not so easy to configure (area concept)

EIGRP at a glance

- Advanced distance vector protocol (can only be used within an AS)
- uses exactly the same metric as IGRP
- Loop avoidance by DUAL
  - DUAL: Diffusing Update Algorithm
  - evolved by Mr. J.J. Garcia-Luna-Aceves
- Event triggered updates (Multicasts)
- Fast convergence

EIGRP at a glance

- Support of multiple unequal-metric paths
- Classless routing protocol (supports route summarization)
  - Update contains network plus prefix
- It supports IP, IPX and AppleTalk
EIGRP Concepts

1st: Every EIGRP router has to discover its neighbors
   - it's done with a Hello protocol
   - a Router doesn't expect an acknowledge for its Hello
   - network type dependent
     - Point-to-point network
     - Multiaccess with broadcast/multicast support (BMA)
     - NBMA nonbroadcast multiaccess network

2nd: based on this Hellos it builds a neighbor table
   - When a newly discovered neighbor is learned, the address and interface of the neighbor is recorded.
   - The HoldTime is the amount of time a router treats a neighbor as reachable and operational: 3 * Hello interval

3rd: After the neighbor discovery a Topology table is built
   - Neighbor routers exchanging their complete routing tables and store these informations in a Topology table
   - information exchange through Update packets
     - Update packets
       - contain a sequence number field in the header and must be acknowledged by the receiver (reliable transmission)
       - are sent in the following instances:
         - when a neighbor first comes up (packet's dest. addr is an unicast)
         - when a network has failed (packet's dest. addr is 224.0.0.10)
         - when there is a metric change for a certain destination (packet's dest. addr is 224.0.0.10)
EIGRP Concepts

- **Update packets**
  - In contrast to OSPF every EIGRP router is modifying any received update packet. It adds its own local distance to the information and sends the packet with an own sequence number to its neighbors.

EIGRP Concepts

- **Topology Table**
  - Stores routing information that neighbors exchange after the first Hello exchange (=> smaller compared to an OSPF topology table). DUAL acts on the Topology table to determine Successors and FSs.
    - **Successor**:
      - A neighbor that has been selected as the next hop for a destination, it ends up in the Routing Table
    - **Feasible Successor (FS)**:
      - A neighbor that has satisfied the Feasibility Condition and has a path to the destination (is an alternate route to the current successor)
    - **Feasibility Condition (FC)**:
      - A condition that is met when the lowest of all the neighbors' costs plus the link cost to that neighbor is found, and the neighbor's advertised cost is less than the current successor's cost.
EIGRP Topology table without feasible successor

Part of R1’s Topology Table

<table>
<thead>
<tr>
<th>Successor</th>
<th>Network</th>
<th>Advertised Distance</th>
<th>Feasible Distance</th>
<th>Neighbor</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>X</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td>R1</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>R3</td>
<td>R2</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>R4</td>
<td>R1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>R5</td>
<td>R4</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>R6</td>
<td>R5</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>R7</td>
<td>R6</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>R8</td>
<td>R7</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**EIGRP Active state**

- If the successor disappears from the topology table because of a network change and there is a feasible successor, **DUAL** keeps the route in a passive state.
  - **Passive state**
    - A router’s state after losing its successor when it has an FS to the destination available in its Topology table.

- If the successor disappears from the topology table because of a network change and there is no feasible successor, **DUAL** puts the route into the active state.
  - **Active state**
    - A router’s state for a destination when it has lost its successor to that destination and has no other feasible successor available. The router is forced to compute a route to the destination.
    - It’s sending a query packet to all its neighbors.
    - **Query packet** (will be acknowledged from the receiver)
      - Sent to all neighbors when a router goes into Active for a destination and is asking for information on that destination. Unless it receives replies back from all its neighbors, the router will remain in Active state and not start the computation for a new successor.
    - **Reply packet** (will be acknowledged from the receiver)
      - Sent by every EIGRP neighbor which receives a query. If the neighbor doesn’t have the information, it queries its neighbors indicating that it is also performing route recomputation.

**EIGRP Active state**

- A router’s state for a destination when it has lost its successor to that destination and has no other feasible successor available. The router is forced to compute a route to the destination.

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EIGRP Compatibility

- **Route tagging**
  - EIGRP has the notion of internal and external routes.
    - Internal routes are ones that have been originated within an EIGRP autonomous system (AS).
    - External routes are ones that have been learned by another routing protocol or reside in the routing table as static routes.
  - **Route redistribution**
    - in the case of IGRP is done automatically, when EIGRP and IGRP are belonging to the same Autonomous System (compatible metric!!). IGRP derived routes are treated as external routes in EIGRP (also OSPF, RIP, EGP, BGP...)

EIGRP Protocol stack

- **OSI stack**
  - IP protocol number 88 (decimal)
  - Data link layer
  - Physical layer